AI4IF_SimonMayer_1

0:00:02

0:49:51

Introductions

Simon Mayer

PhD in Computer Science, ETH Zurich (→ 2014)
- Hypermedia-based interactions with and between smart devices ("**Interacting with the Web of Things**")
- Visiting Researcher at MIT (2012; Connected Cars) and at Ghent University (2013; Semantic Technologies & AI Planning)
- Master of Advanced Studies in Secondary and Higher Education (ETH Zurich, 2014)
- BA in Business and Economics (University of Zurich, 2014)

Senior Key Expert, Siemens Corporate Technology, Berkeley (→ 2017)
- Senior Key Expert for Smart and Interacting Systems
- **Horizontal and vertical interoperability in distributed industrial systems** (manufacturing, smart grids, mobility)

RG Head "Cognitive Products" at Pro²Future + Postdoctoral Researcher at TU Graz (→ 2018)
- Interacting and **cooperating smart products; interactions of smart products and people**

Lecturer at ETH Zurich (2015 →), MIT (2015), UC Berkeley (2015-2017), and TU Graz (2017-2019)

Full Professor of Interaction- and Communication-based Systems at HSG
Senior Scientist at ETH Zurich

Pro²Future

TU Graz

Berkeley

MIT

TU Graz

University of St.Gallen

ETH zürich

01:01 49:53
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The Web of Things and Hypermedia for Smart Devic

In this lecture, we explore using the Web to **boost application-layer interoperability of Internet of Things devices and services** and as a foundation to **facilitate their usage by clients**.

We discuss principles of the Web of Things, focusing on the design of Web APIs for smart devices and on the usage of hypermedia as the engine of application state.

Sources:

S. Mayer & A. Ciortea: Ubiquitous Computing and the Internet of Things, University of St.Gallen, 2020
F. Mattern and S. Mayer: Ubiquitous Computing, ETH Zurich, 2019

Learning Goals

The goal of this lecture is to enable you to:

- **understand** how the Web supports application-level interoperability in the IoT.
- **build** better Web APIs for devices (and other resources).
- **appreciate** the role that hypermedia plays in guiding Web clients.

In the context of the summer school, this should enable you to **perceive hypermedia-based information systems as playgrounds for interacting humans and machines.**

Reinforcing the previous talks by Matthias and Andreas and together with technologies from the **Semantic Web (Tobias)** and from **Multi-Agent Oriented Programming (Jomi)**, this will supply you with a toolset to build **«ideally interoperable» industrial Internet of Things systems.**

Our Menu

From the IoT to the WoT: Network-level and Application-level Interoperability
Discussion: Good Practices for Web APIs
Tidbits from the Web Architecture
Hypermedia APIs

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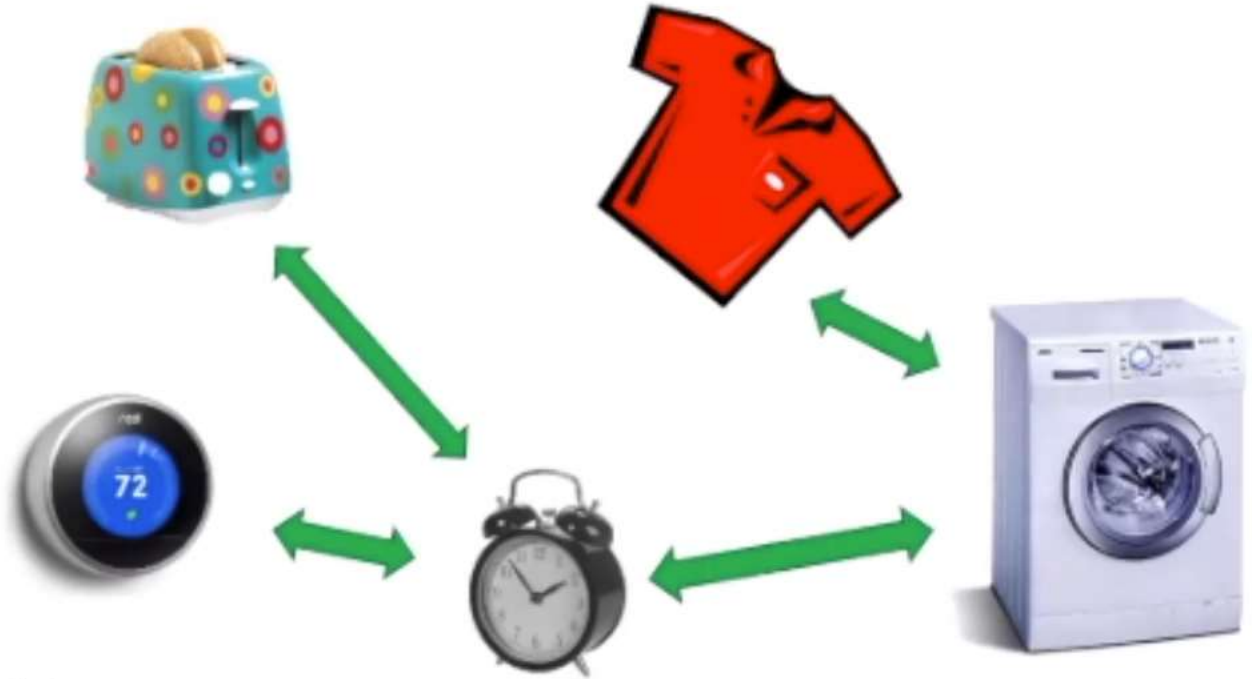
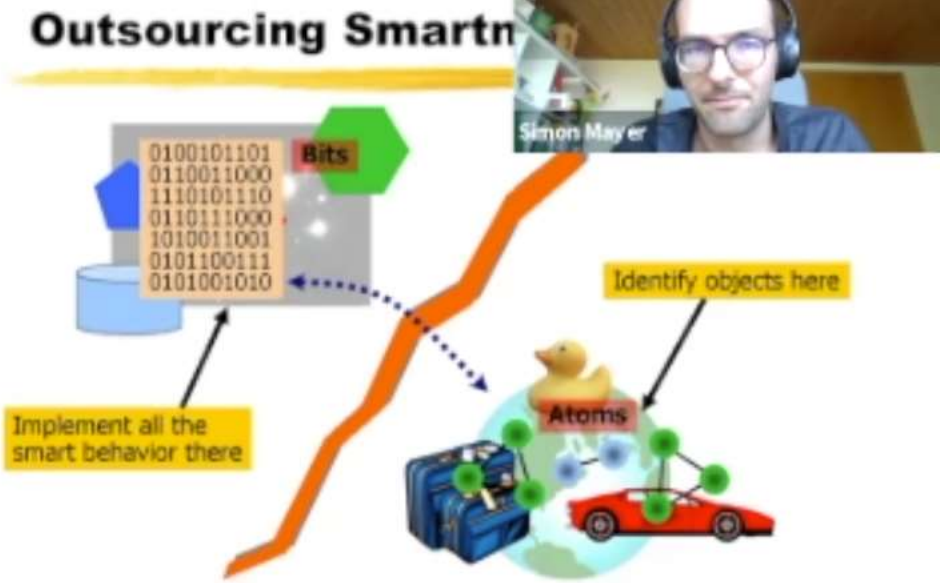
Ubiquitous Computing



The "Social Web of Things" (Ericsson, design study)

- Note the **explicit communication** between David and his home
- Note the **hidden communication** between his smart devices
- Note the **partially autonomous** behavior of the smart environment

Ubiquitous Computing

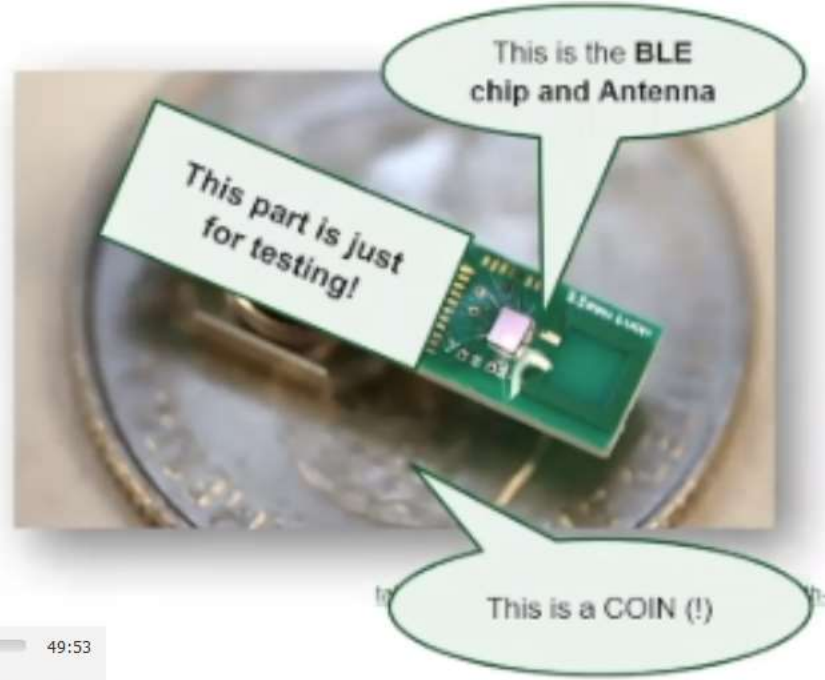


Wireless (and cheap) access to the Internet

- For **any thing** (→ low-power, passive)
- At **any place** (→ mobile, ubiquitous)
- **Without configuration** ("plug & play" → "arrive & operate")

Object communication **dominates** network usage

- **Real-world objects** will access and use services on the Web and services that are provided by other nearby devices
- They might even integrate with and use these services **autonomously**



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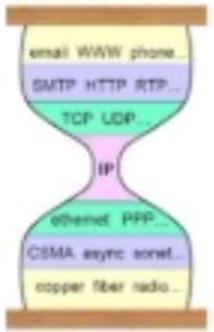
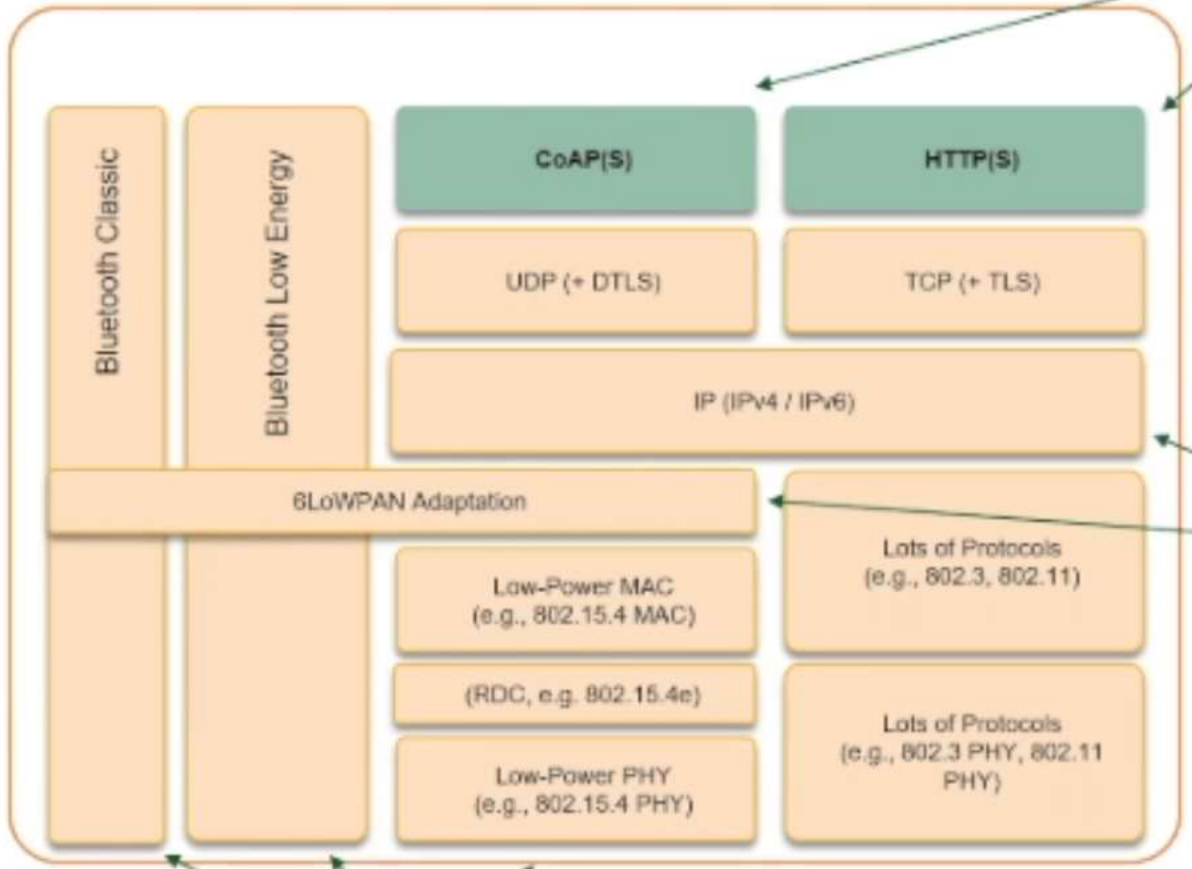
Distributed Systems Design Space



Source: Steve Deering, Talk at IETF 51, 2001

Interoperability on the **Application Layer**



Interoperability on the **Network Layer**

Networking of **Tiny Devices**

LoRa

Ubiquitous Computing

e.g., BLE

UbiComp applications require…

- Reduced power consumption, reduced cost, reduced size, near real-time operation (i.e., small latency)
- **Network-layer** connectivity and integration
- **Application-layer** integration and interoperability: **Web of Things**
- **Semantic-layer** interoperability and understanding: **See tomorrow** ;-)

6LoWPAN
IPv6-based Low-power Wireless Personal Area Networks

Avoid Network/Application/Semantic Fragmentation of Distributed Systems

Why?

To enable exploiting «network effects»!

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Network Effects: The Internet Protocol

ICMP: Not for data exchange…
IPsec: Security layer on top of IP
IGMP: *Replaced* by IPv6 Group Management
Xerox IPX: *Replaced* by IP (1998)
AppleTalk: *Replaced* by IP (1990-2009) [-> Bonjour]
ITU-T X.25 PLP: *Replaced* by IP (~2012; still used in niche applications)

3. Network layer [hide]
IP (IPv4 · IPv6) · ICMP · IPsec · IGMP · IPX · AppleTalk · X.25 PLP

Google Interest over time in AppleTalk, X.25, IPSec, IPX, IGMP

7. Application layer [hide]
NNTP · SIP · SSI · DNS · FTP · Gopher · HTTP · NFS · NTP · SMPP · SMTP · SNMP · Telnet · DHCP · Netconf · *more…*

6. **Presentation layer** [hide]
MIME · XDR

5. **Session layer** [hide]
Named pipe · NetBIOS · SAP · PPTP · RTP · SOCKS · SPDY

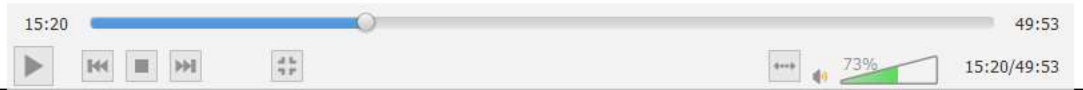
4. **Transport layer** [hide]
TCP · UDP · SCTP · DCCP · SPX

3. **Network layer** [hide]
IP (IPv4 · IPv6) · ICMP · IPsec · IGMP · IPX · AppleTalk · X.25 PLP

2. **Data link layer** [hide]
ATM · ARP · IS-IS · SDLC · HDLC · CSLIP · SLIP · GFP · PLIP · IEEE 802.2 · LLC · MAC · L2TP · IEEE 802.3 · Frame Relay · ITU-T G.hn DLL · PPP · X.25 LAPB · Q.921 LAPD · Q.922 LAPF

1. **Physical layer** [hide]
EIA/TIA-232 · EIA/TIA-449 · ITU-T V-Series · I.430 · I.431 · PDH · SONET/SDH · PON · OTN · DSL · IEEE 802.3 · IEEE 802.11 · IEEE 802.15 · IEEE 802.16 · IEEE 1394 · ITU-T G.hn PHY · USB · Bluetooth · RS-232 · RS-449

V · T · E



IP: The Narrow Waist of Networking

ICMP: Not for data exchange…
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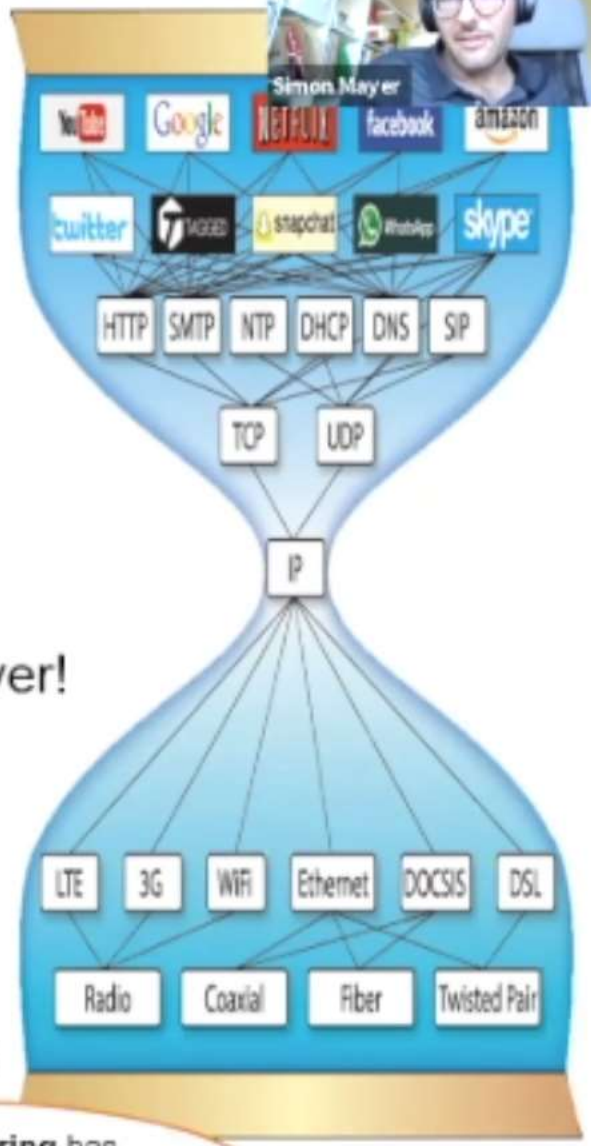
"*IP over everything, everything over IP*" is the **biggest network effect** ever!

- Fundamental goal: interconnect **heterogeneous** systems
- Fundamental requirement: **global** addressing scheme

Drawback?

- Adding functionality in the network layer is extremely difficult!
- This is exemplified in the **tedious decade-long process** of switching from IPv4 to IPv6



In general, **layering** has worked out very well for computer networks…

The Internet of Things

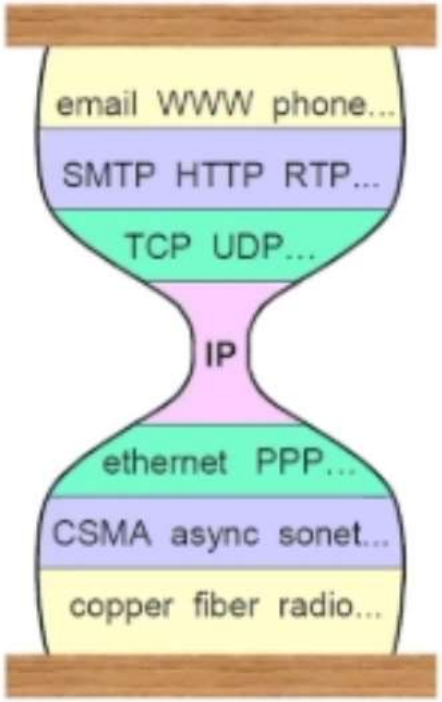
IoT = Internet of Things = **IP-enabled Physical Devices**

Original Internet of Things Idea

- Extend that biggest network effect ever to **physical devices**
- One network for **heterogeneous physical systems**
- Stretching into **low-power** systems as well (e.g., LoWPANs)

e.g., in the smart home space: https://www.connectedhomeip.com/

amazon · Google · zigbee alliance · IKEA · legrand · LEEDARSON · NXP · resideo · SmartThings · Schneider Electric · signify · SILICON LABS · somfy · Wulian



Source: Steve Deering, Talk at IETF 51, 2001

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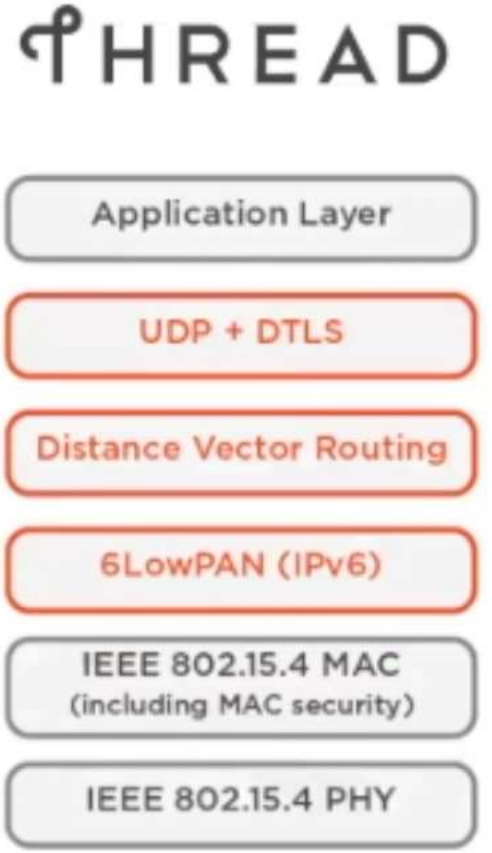
Thread: Branding Low-power Mesh Networking for

Backed by lots of relevant companies

- "Thread Group" Interest Group
- Nest Labs / Alphabet, Apple, Samsung
- ARM, Qualcomm, NXP
- OSRAM, Tyco

Thread = a "stack brand name"

- 802.15.4 for the lower layers
- **6LoWPAN for IPv6 compatibility**
- **IP routing for network**
- UDP for little overhead
- DTLS for security
- **"Any" application layer** (should support constrained devices…)



https://www.electronicdesign.com/iot/engineering-essentials-iot-standards-and-frameworks

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History…

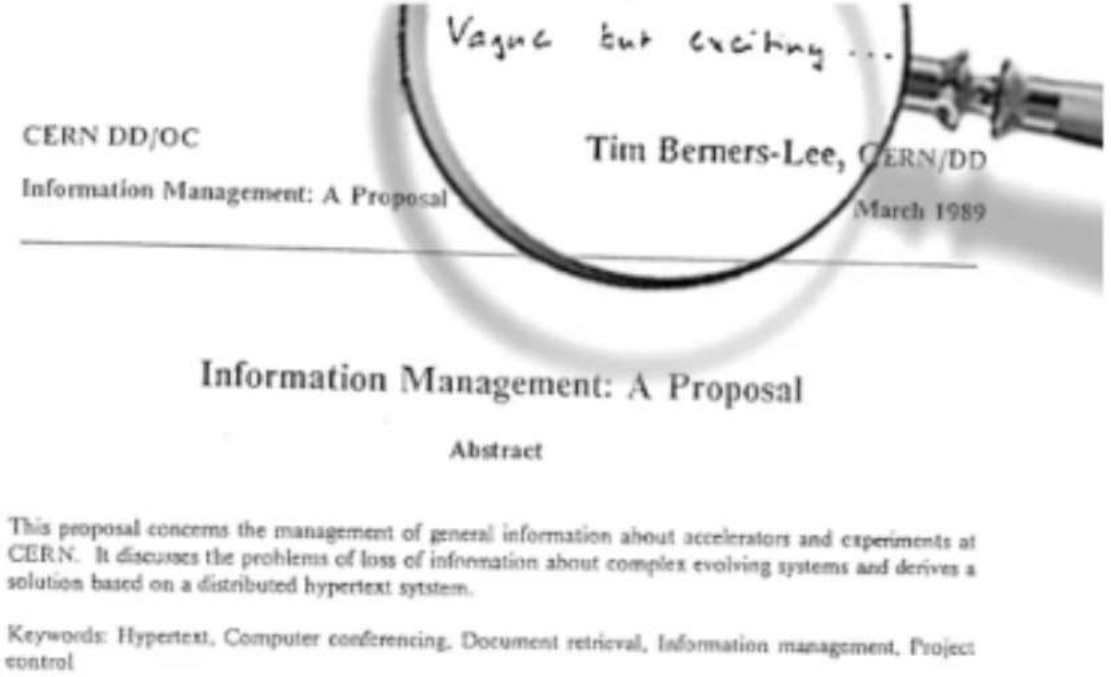
Which Olympic Games were the first to have an **official** Website?

- Sydney 2000
- Atlanta 1996
- Athens 2004
- Barcelona 1992
- Beijing 2008

20:04 49:53 73% 20:04/49:53

The **World Wide Web** made the Internet popular…

1989: Tim Berners-Lee submits a proposal for an information management system at CERN to his boss, Mike Sendall (http://info.cern.ch/Proposal.html)



Vague but exciting ...

CERN DD/OC

Tim Berners-Lee, CERN/DD

Information Management: A Proposal

March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext system.

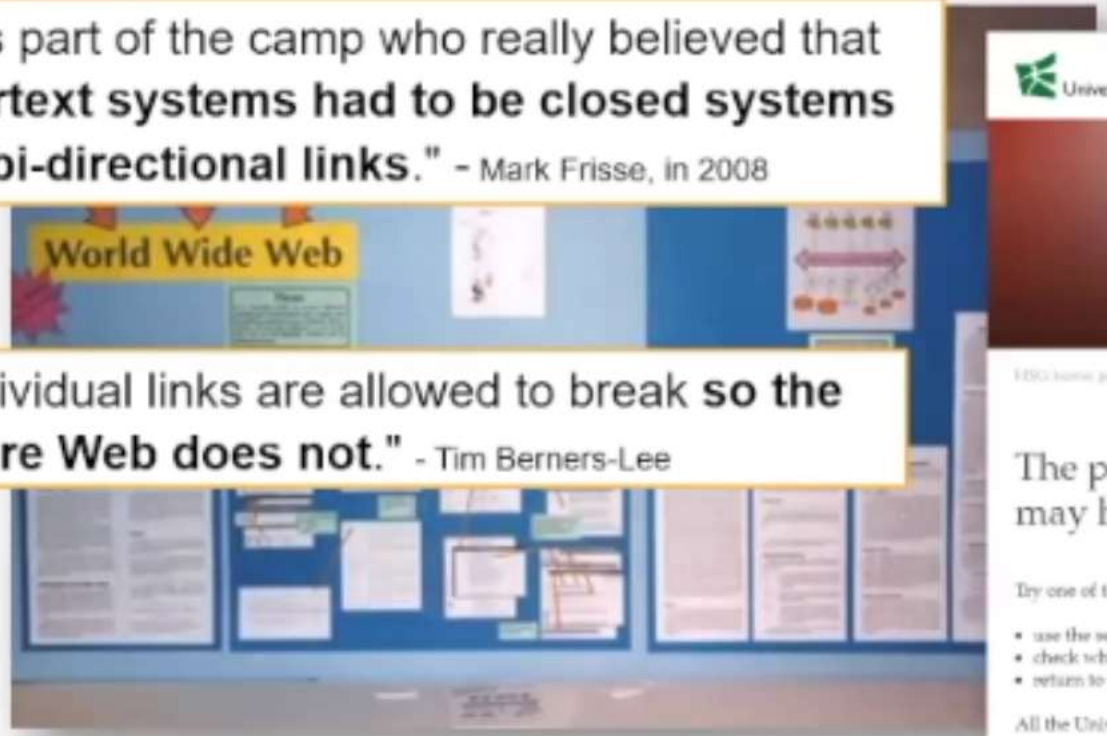
Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control

1990: Berners-Lee defines the terms **URI** (then UDI), **HTTP**, and **HTML**, and develops the first components and tools for the Web (browser, editor, server, line-mode browser)

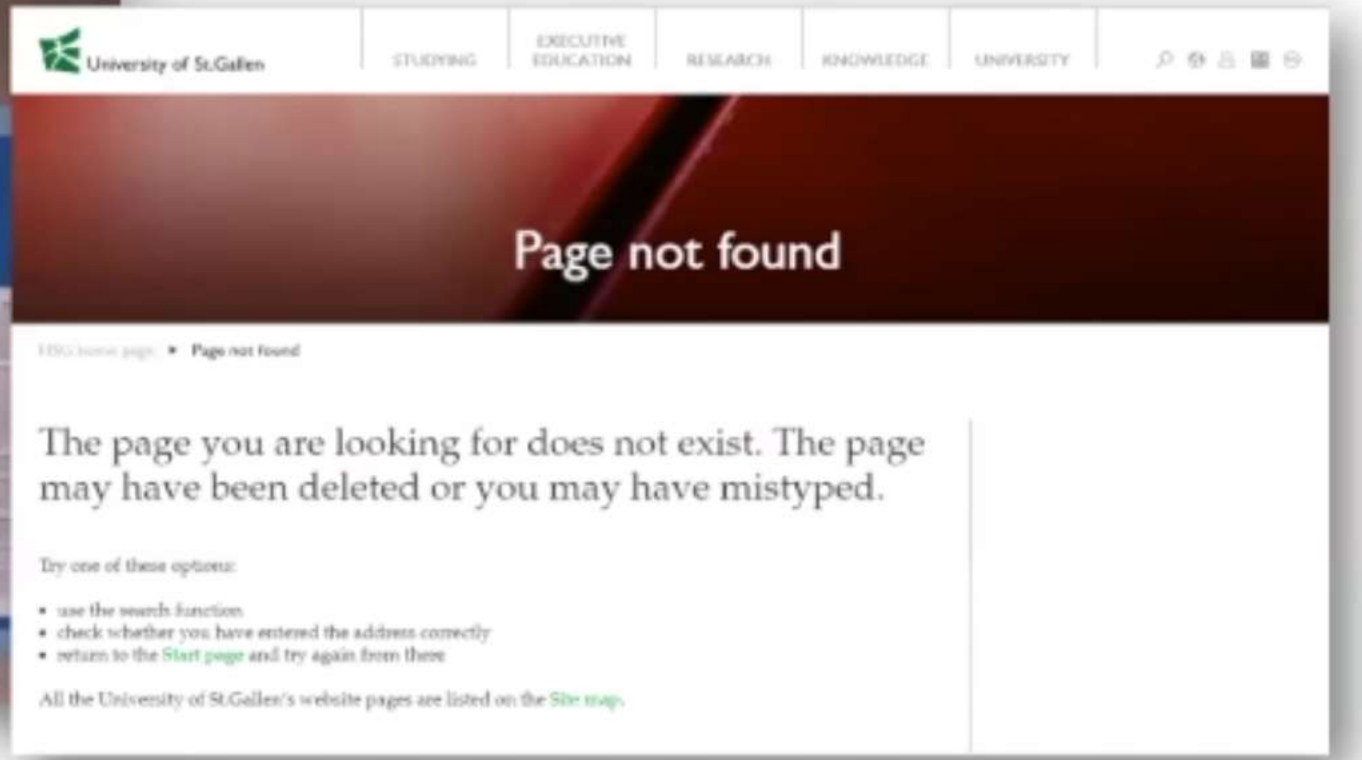
The **World Wide Web** made the Internet popular…

1991: Tim Berners-Lee submits a paper on the Web to the *Hypertext '91 Conference*.
The paper is **rejected as an oral presentation** and only accepted as a **poster** contribution…

"I was part of the camp who really believed that **hypertext systems had to be closed systems with bi-directional links**." - Mark Frisse, in 2008



"Individual links are allowed to break **so the entire Web does not**." - Tim Berners-Lee



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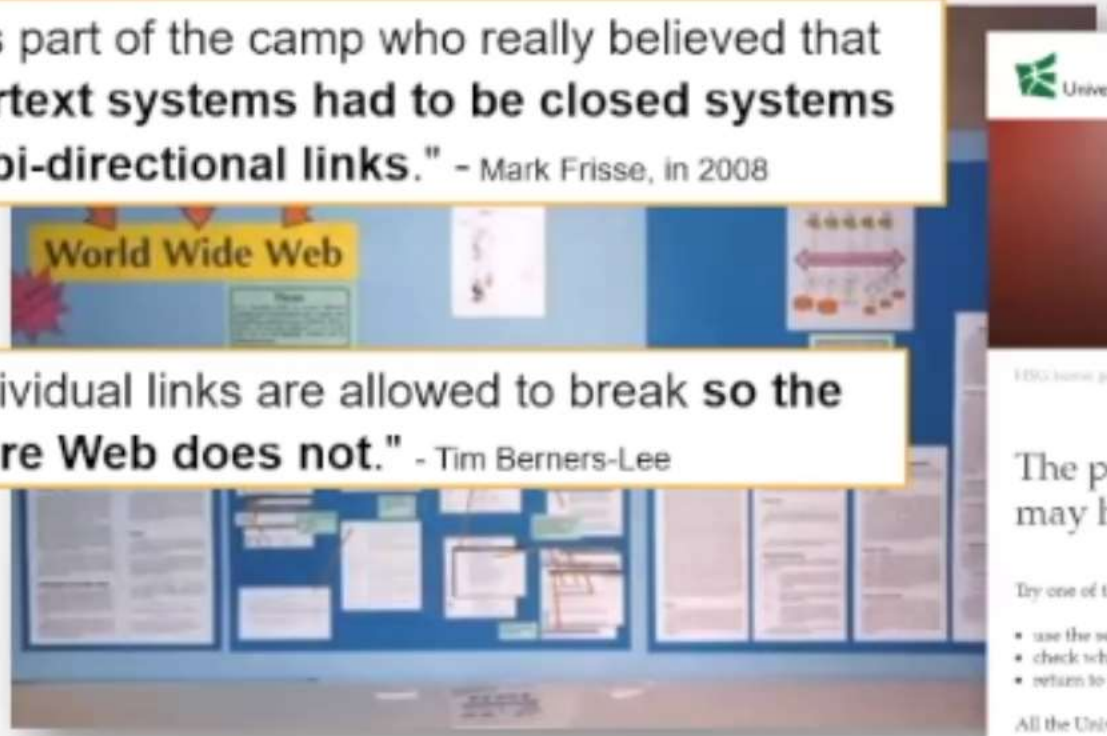

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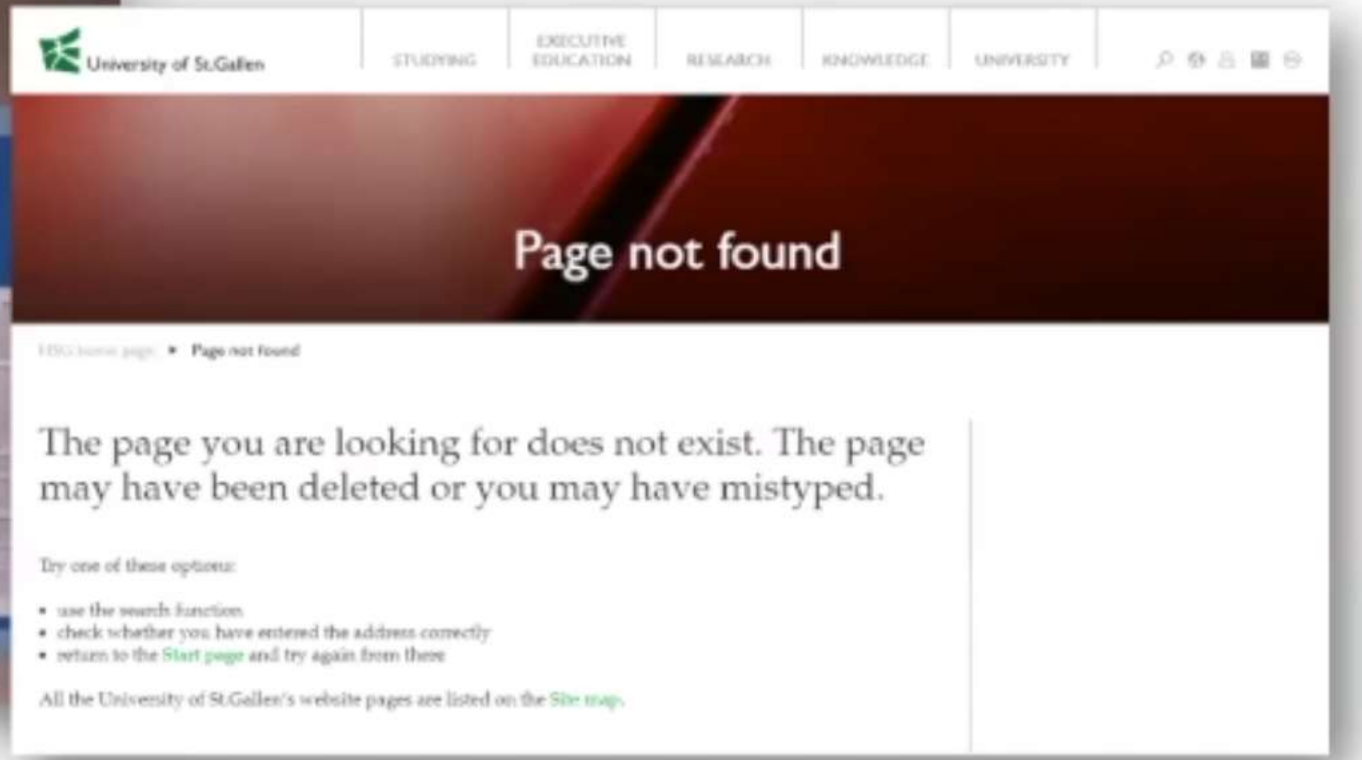

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SRF Schweizer Radio und Fernsehen SRF Online

GE Digital

Wikipedia The Free Encyclopedia

Parship

HILTI ON!Track

intuit turbotax

Answers

SAMSUNG

nest

MindSphere

Foodarena.ch

POLITICO

YouTube

The **World Wide Web** is an information system where **resources** are identified by **Uniform Resource Identifiers** (URIs) which are accessible over the **Internet**, and may be interlinked by **hyperlinks**.

….stretching to **physical devices** as well!

23:03 49:53 73% 23:03/49:53

Even Tiny Devices!

HTTP is not the only player out there!

CoAP has been designed from scratch following the REST architectural style.

The target scenario for CoAP is one of **constrained** nodes and networks

- Constrained nodes can be sensors with **limited memory and processing** power
- Constrained networks can be **slow** and **unreliable** and **intermittent**
- **TCP performs poorly** in low-power wireless networks
- CoAP is optimized for bandwidth and processing efficiency

CoAP

CoAP Properties

- Very **efficient** REST on top of UDP
- **Lightweight security** to prevent eavesdropping, tampering, forgery
- Specialized for M2M applications: **Multicast** & **Observe**!
- Easy to proxy from/into HTTP but not a general replacement for HTTP

23:44
23:45 49:53
73% 23:45/49:53

Dotdot over Thread

Thread

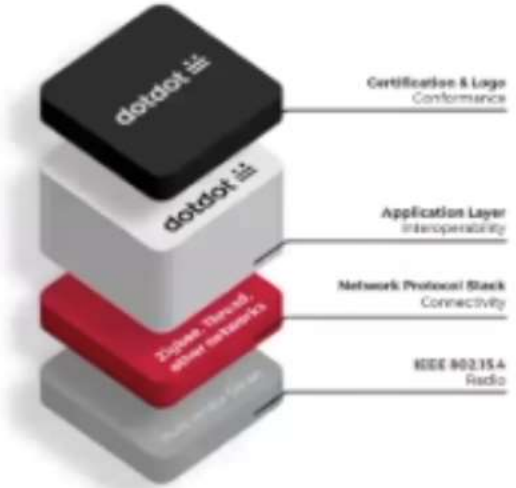
- 802.15.4 for the lower layers
- 6LoWPAN for IPv6 compatibility
- IP routing for network
- UDP for little overhead
- DTLS for security
- "Any" application layer (should be low-bandwidth though…)

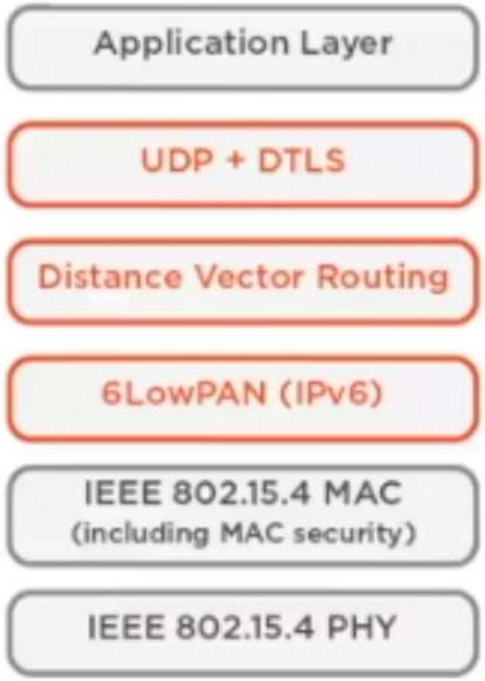
Dotdot = An "application layer brand name"

- CoAP + CoRE Link Format

"Built with the open standards and global membership of the Zigbee Alliance, Dotdot gives us the freedom to choose the brands and products that transform the way we live, work, and play."

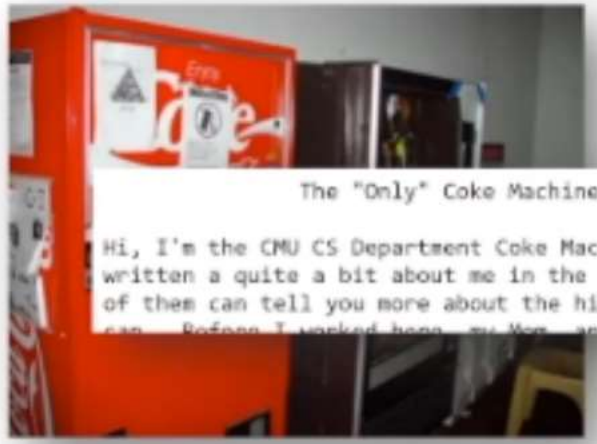
https://zigbeealliance.org/solution/dotdot/





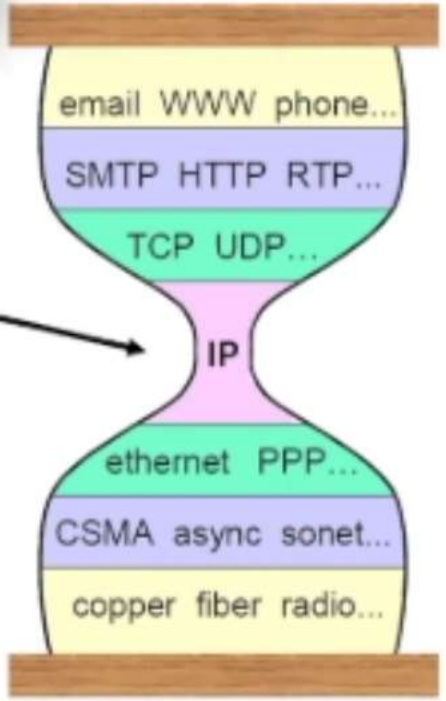
https://www.electronicdesign.com/iot/engineering-essentials-iot-standards-and-frameworks

The IoT and the WoT



Original Internet of Things Idea

- Extend the **biggest network effect ever** to physical devices
- **IP-over-Everything, Everything-over-IP**
- One network for **heterogeneous systems**
- Even integrating LoWPANs!



Original and Current WoT Ideas

- Apply Web principles to **defragment the IoT's application layers**
- Apply Web principles to **simplify the creation of applications** on top of networked devices
- Apply Web principles to make such **WoT mashups easily usable by people**

Source: Steve Deering, Talk at IETF 51, 2001

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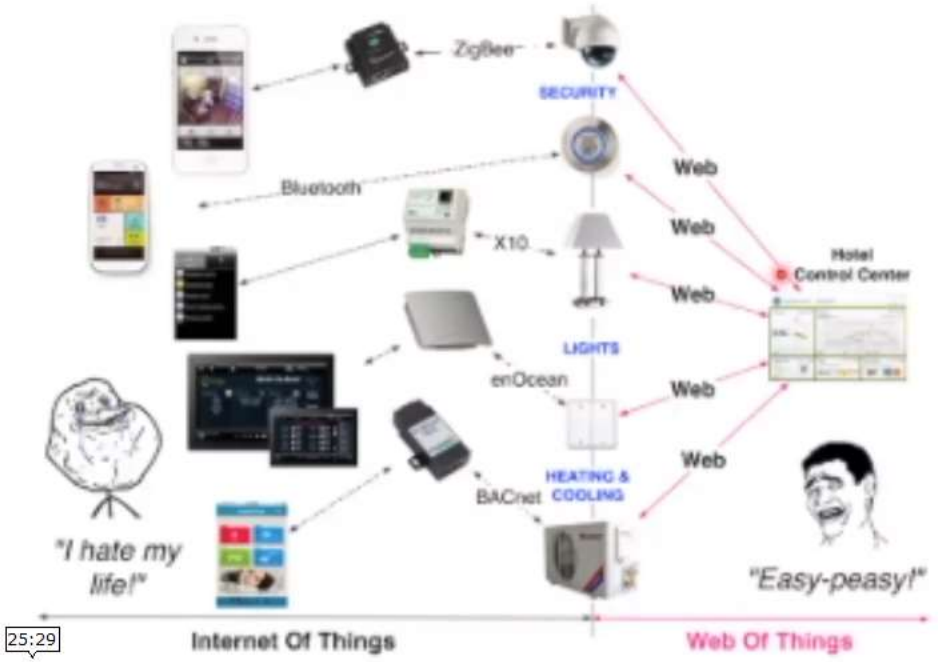
yelp

BART

Bay Area
Rapid Transit



Guinard and Trifa, 2012

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Demonstration: A Mashupping Exercise!

Setup

- Ubiquitous Computing course at ETH Zurich (2016)
- 50 Students (70% MSc, 30% BSc; 70% CS Students)

Task

– Work with the: **Bay Area Rapid Transit** (BART) & **Yelp Fusion APIs**
– Write a mashup that, given a BART station identifier, lists the 5 best-rated restaurants around that station

Time is of the essence: prizes for 1st 2nd 3rd place

Bay Area
Rapid Transit

26:30 49:53
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Demonstration: A Mashupping Exercise!

(divided by the minutes needed to solve the challenge…)

26:39
26:40 49:53
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Demonstration: A Mashupping Exercise!

Solved successfully by 20 teams within the time limit

Submitting students: Felix, Jonathan, Johnathan, Dominik, Tobi, Martin, Andrei, Chris, Nino, Dominik, Thomas, Balz, Ingo, Martina, Simon, Emily, Krisztina, Yongzhe, Mrigya, Daniel

yelp

4th prize:	50min
3rd prize:	39min
2nd prize:	31min
1st prize:	**24min**

BART Bay Area Rapid Transit

i.e.: a **trained individual can use the Web to create a useful (potentially commercializable) application** while someone else **is in their coffee break**.

University of St.Gallen

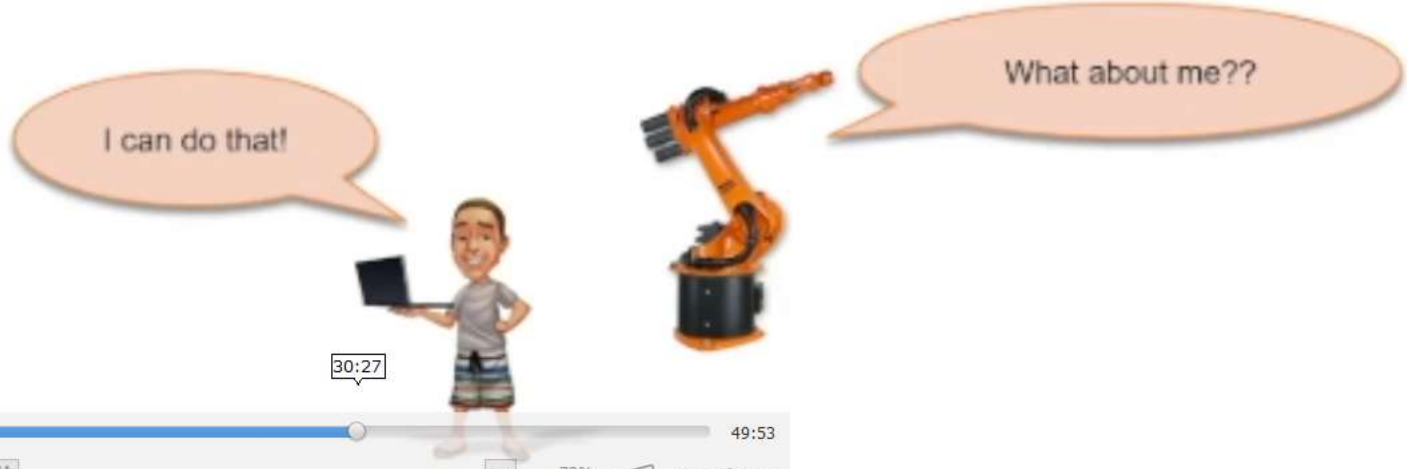
Demonstration: A Mashupping Exercise!

If you want people to use your API, it **must be easy to develop for**!

- **Simple to use**: use widespread patterns and formats
- **Simple to register for**: if a more advanced authentication scheme is used, this must be documented properly
- **High-quality API documentation**
- **Example code and/or client libraries**

These factors make your API easy to use – **for humans**!

Current research concerns **how to make APIs easy to use for machines** ;-)



Sneak Preview

University of St.Gallen
Institute of Computer Science
ICSN, HS2019
Simon Mayer & Iori Mizutani
simon.mayer@unisg.ch; iori.mizuta

Assignment 4: The Bits go Global (7pt)

Deadline: December 11, 2019; 16:00 CET

(3) Your Sensor goes Global (2pt)

Although you'll only be creating a basic Web server in this task, have a look at the current IRTF recommendations for *RESTful Design for Internet of Things Systems*.[5] Next, create a simple Web server that enables you to read the most recently measured temperature value of your DS18B20 sensor via an HTTP GET request to your Raspberry Pi. You are free to design and implement this Web server from scratch – it is however also permissible that you use the *OpenAPI* API description format for specifying your sensor's Web API and then use the *swagger* tool[6] to automatically generate server code that you can deploy on your RPi. Finally, integrate the (generated) server with the code that accesses the temperature sensor and verify that your system works correctly by accessing the RPi's Web server remotely from a browser or using the Postman application. If you chose to have the server code generated, make sure that you understand it.

(4) Physical Mashups! (2pt)

For this task, we provide you with a Web API (OpenAPI description: `https://interactions.ics.unisg.ch/leubot`) to control a *PhantomX Reactor Robot Arm*[7] that is installed in our laboratory space (the robot's name is "Leubot").

Try out the API by reading the description and composing a set of requests to move the arm around. You can verify the robot arm's behavior by checking the live video stream of the robot[8].

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73% 33:25/49:53

Sneak Preview

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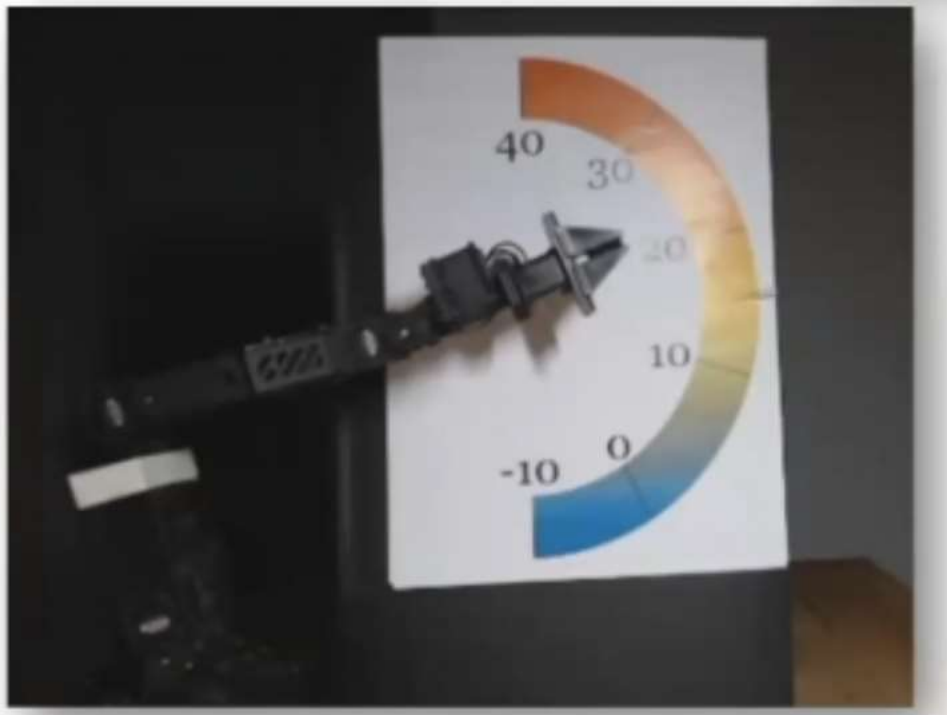
Deadline: December 11, 2019; 16:00 CET

app.swaggerhub.com/apis-docs/iomz/leubot/1.2.1#/user/removeUser



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If creating a robot mashup is this simple, «Industry 4.0» is just a matter of time.
If creating a robot mashup is this simple, **this process can perhaps be fully automatied**…

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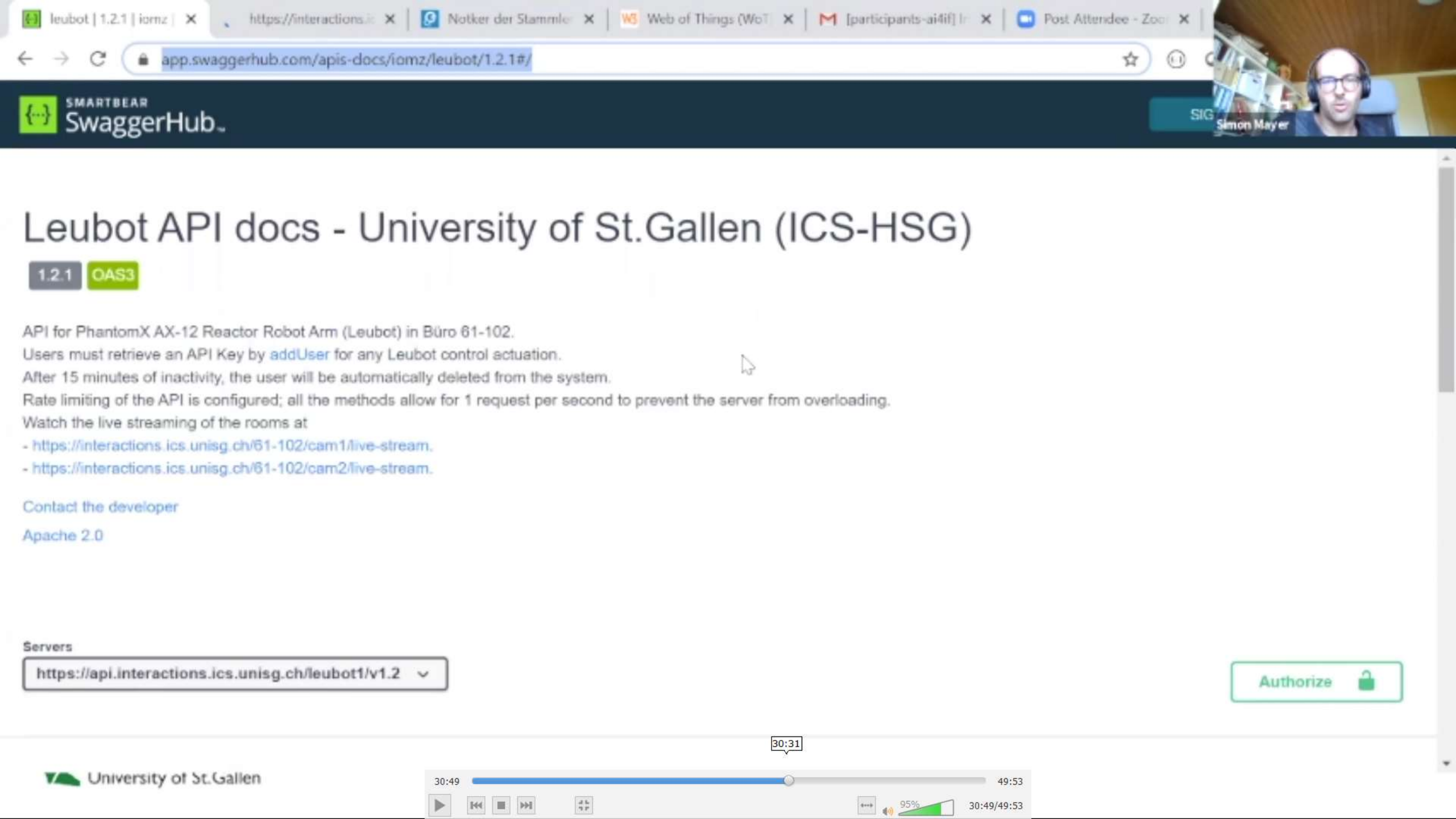
73% 35:38/49:53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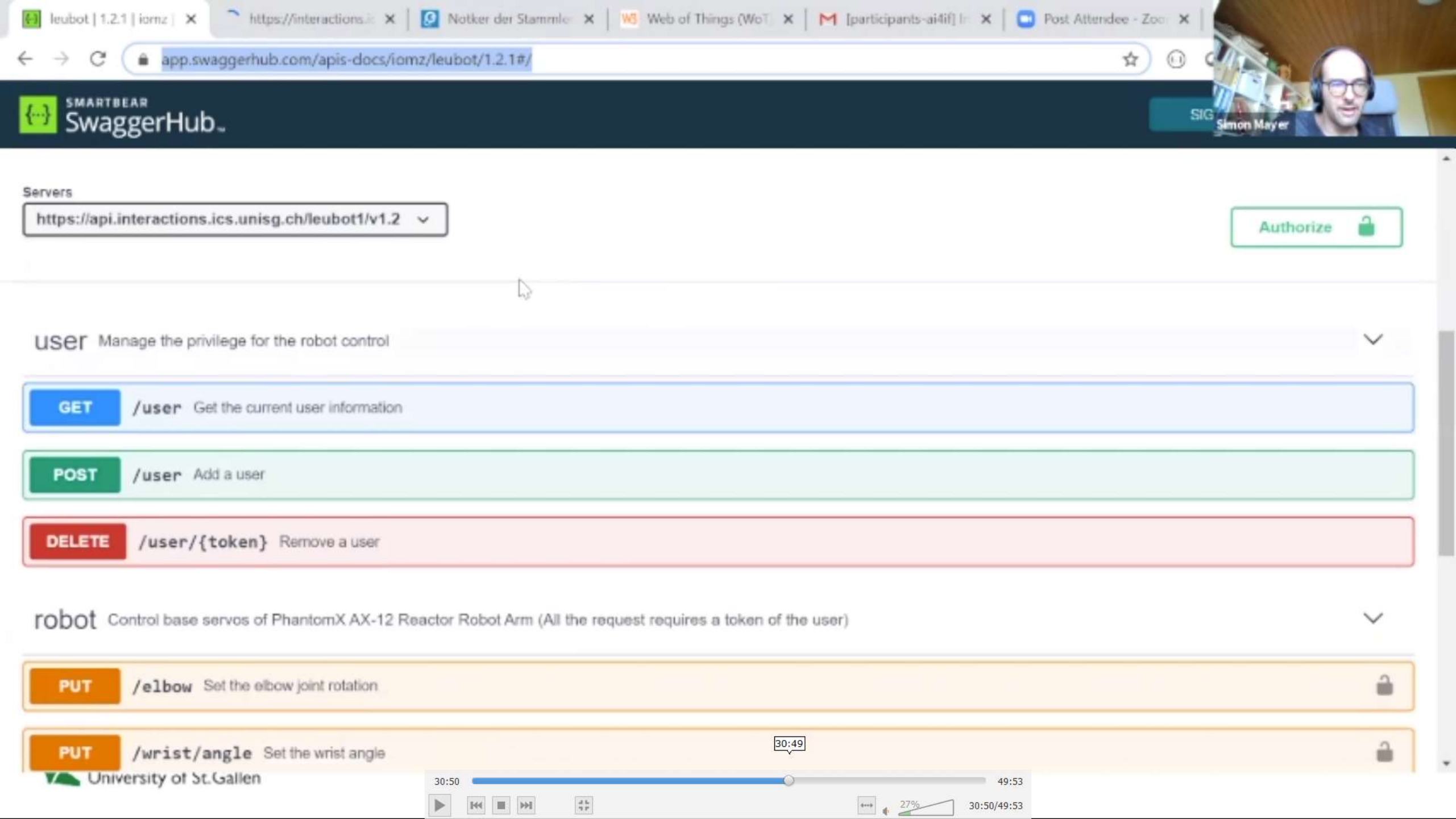
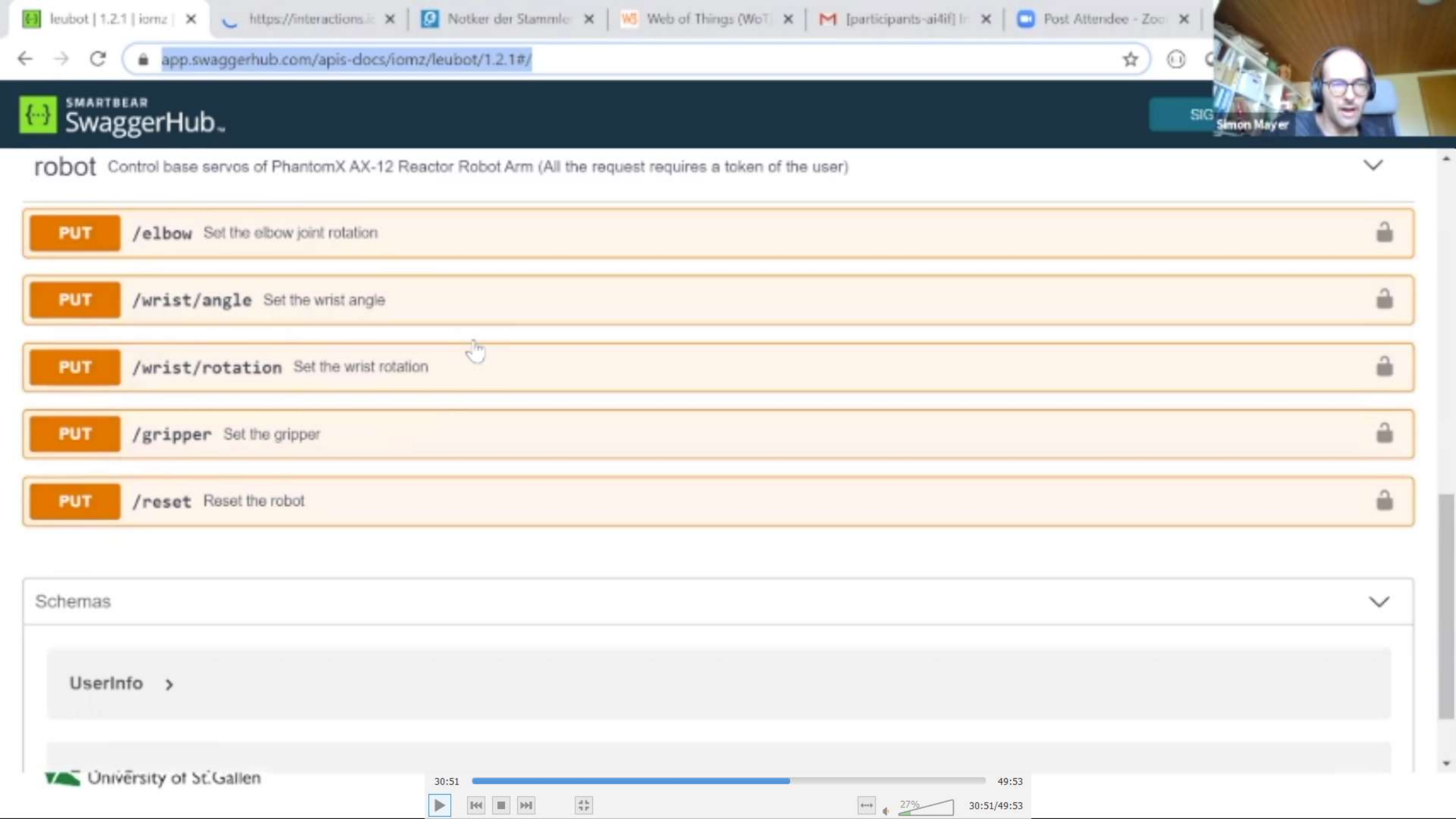
https://interactions.ic
Notker der Stammle
Web of Things (WoT
[participants-ai4if] In
Post Attendee - Zoo
app.swaggerhub.com/apis-docs/iomz/leubot/1.2.1#/
SMARTBEAR
SwaggerHub
SIG
Simon Mayer
Leubot API docs - University of St.Gallen (ICS-HSG)
1.2.1
OAS3
API for PhantomX AX-12 Reactor Robot Arm (Leubot) in Büro 61-102.
Users must retrieve an API Key by addUser for any Leubot control actuation.
After 15 minutes of inactivity, the user will be automatically deleted from the system.
Rate limiting of the API is configured; all the methods allow for 1 request per second to prevent the server from overloading.
Watch the live streaming of the rooms at
- https://interactions.ics.unisg.ch/61-102/cam1/live-stream.
- https://interactions.ics.unisg.ch/61-102/cam2/live-stream.
Contact the developer
Apache 2.0
Servers
https://api.interactions.ics.unisg.ch/leubot1/v1.2
Authorize
30:31
University of St.Gallen
30:49
49:53
95%
30:49/49:53


leubot | 1.2.1 | iomz
app.swaggerhub.com/apis-docs/iomz/leubot/1.2.1#/
SMARTBEAR
SwaggerHub
Simon Mayer
Servers
https://api.interactions.ics.unisg.ch/leubot1/v1.2
Authorize
user Manage the privilege for the robot control
GET /user Get the current user information
POST /user Add a user
DELETE /user/{token} Remove a user
robot Control base servos of PhantomX AX-12 Reactor Robot Arm (All the request requires a token of the user)
PUT /elbow Set the elbow joint rotation
PUT /wrist/angle Set the wrist angle
30:49
University of St.Gallen
30:50
49:53
27%
30:50/49:53


leubot | 1.2.1 | iomz
app.swaggerhub.com/apis-docs/iomz/leubot/1.2.1#/
SMARTBEAR
SwaggerHub
Simon Mayer
robot Control base servos of PhantomX AX-12 Reactor Robot Arm (All the request requires a token of the user)
PUT /elbow Set the elbow joint rotation
PUT /wrist/angle Set the wrist angle
PUT /wrist/rotation Set the wrist rotation
PUT /gripper Set the gripper
PUT /reset Reset the robot
Schemas
UserInfo
University of St.Gallen
30:51
49:53
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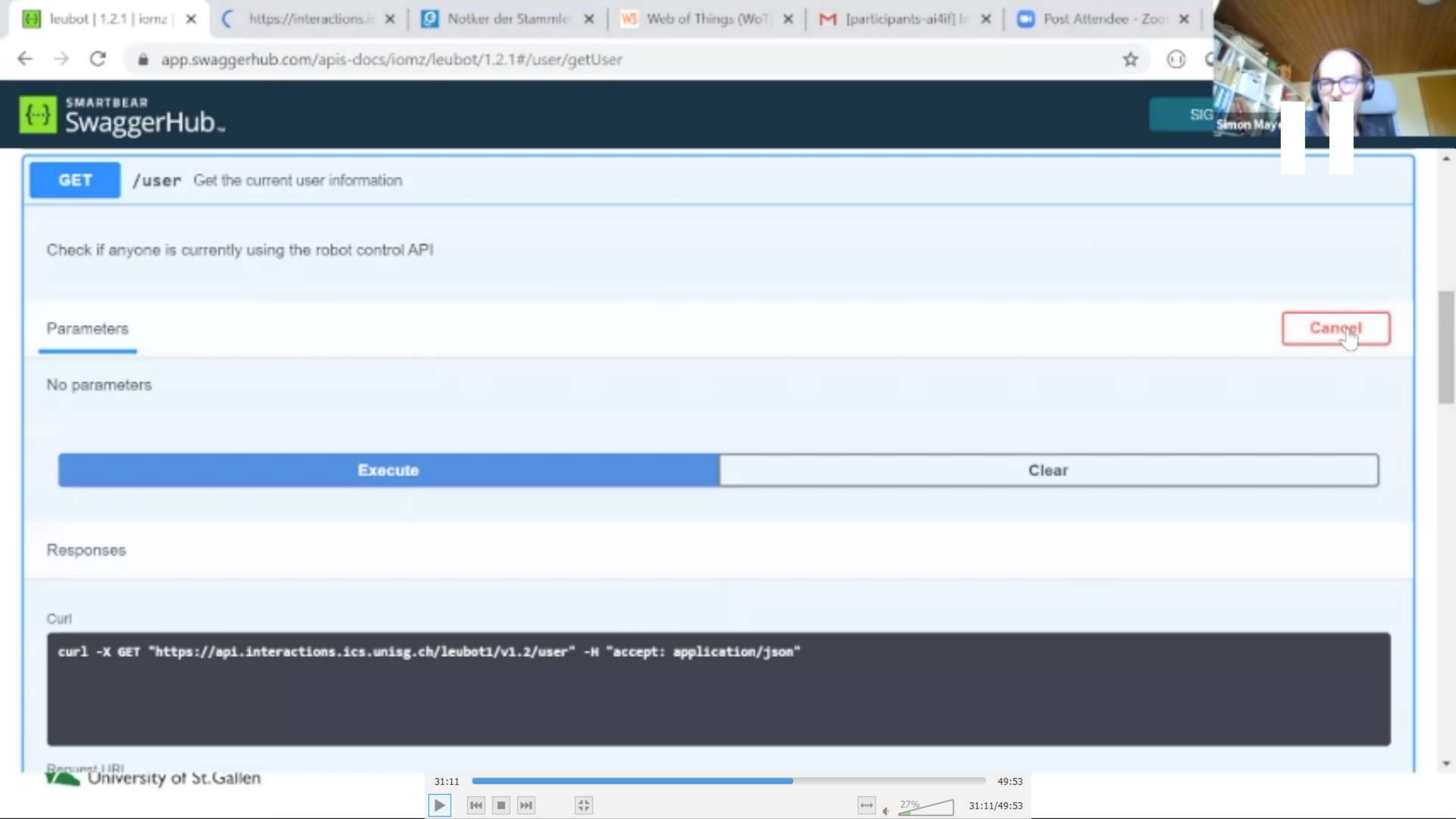
30:51/49:53


leubot | 1.2.1 | iomz
https://interactions.ic
Notker der Stammle
Web of Things (WoT
[participants-ai4if] In
Post Attendee - Zoo
app.swaggerhub.com/apis-docs/iomz/leubot/1.2.1#/user/getUser
SMARTBEAR
SwaggerHub
SIG
Simon May
GET
/user
Get the current user information
Check if anyone is currently using the robot control API
Parameters
Cancel
No parameters
Execute
Clear
Responses
Curl
curl -X GET "https://api.interactions.ics.unisg.ch/leubot1/v1.2/user" -H "accept: application/json"
Request URL
University of St.Gallen
31:11
49:53
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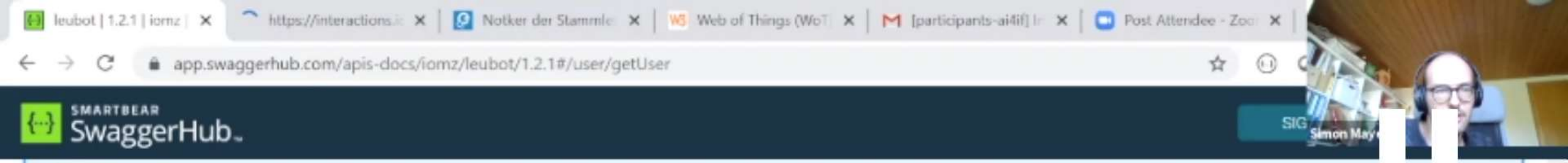
31:11/49:53



Server response

Code	Details

200

Response body

```
{
  "name": "",
  "email": ""
}
```

Download

Response headers

```
cache-control: no-cache
content-length: 22
content-type: application/json; charset=UTF-8
date: Mon27 Jul 2020 12:11:23 GMT
etag: W/"16-fk+yUvFtt/aj6u/GqRkQeHk7/f8"
expires: -1
server: nginx/1.14.1
status: 200200 OK
via: 1.1 c76347c8ef1f3a2b6fb69cd7d1c6f749.cloudfront.net (CloudFront)
x-amz-cf-id: guNm3jvdST1N4yYt7WTlRXFsXyJWF77WBLm0n5PS52YfL5LntNwWBA==
x-amz-cf-pop: ZRH50-C1
x-cache: Miss from cloudfront
x-powered-by: ExpressPhusion Passenger 5.3.4
```

Request duration

```
1320 ms
```

Responses

Point in Case: The Europeana Website

(example from R. Verborgh: Web Fundamentals Introduction)

Europeana: Aggregates and exposes **cultural heritage metadata** from more than 2000 institutions (British Library, Louvre, Stiftsbibliothek St. Gallen, etc.) – requires a **long-term architectural vision**

Europeana resources are identified by URIs:
https://www.europeana.eu/portal/en/record/9200143/BibliographicResource_2000069304654

Europeana publishes its data…

- On a website with content negotiation (HTML and JSON)
- Via a dedicated machine API

Using the Europeana website as a **machine** is thus possible in **two ways**

1. Use the regular website and request JSON data
2. Use the dedicated machine API

What do you think: **Which one is easier to implement?**

38:25 49:53
27% 38:25/49:53

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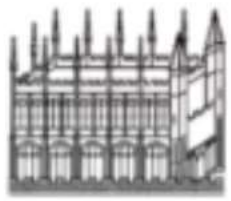
https://interacti
Notker der Stam
Web of Things
[participants-ai
Post Attendee
Notker der Stam
europeana.eu/en/item/9200143/BibliographicResource_2000069304654
Simon Mayer

europeana

Search millions of items

You're viewing this item in the new Europeana website. View this item in the original Europeana.



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Notker der Stammler, Mönch von Sankt Gallen, über die taten Karls des Grossen nach der ausgabe der Monumenta Gernmaniae

Gesta Caroli Magni

Edition: 5

5. aufl.

CONTENT YOU MIGHT LIKE

Notker the Stammerer

Sichere Verbindung wird hergestellt...

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Point in Case: The Europeana Website

(example from R. Verborgh: Web Fundamentals Introduction)

Accessing https://www.europeana.eu/portal/en/record/9200143/BibliographicResource_2000069304654 as a machine client...

Option 1: Use the **regular website** and request JSON data

1. Set a request header to "Accept: application/json"
2. Request the data at https://www.europeana.eu/portal/en/record/9200143/BibliographicResource_2000069304654
3. Do whatever you wanted to do…

Option 2: Use the **dedicated machine API** (see https://gist.github.com/RubenVerborgh/7684361/#gistcomment-959892)

1. Read the documentation
2. Get an API key
3. Find the right URL template for the API call
4. Find out the object ID of your object (non-trivial beca
5. Fill out the template to construct the URL
6. Retrieve a representation using this URL
7. Do whatever you wanted to do…

*All of this was not required for the human-readable website, even though the **retrieved information is exactly the same**, just the format is different!*

gist.github.com/RubenVerborgh/7684361/#gistcomment-959892

DavidHaskiya commented on 28 Nov 2013

Hi Ruben,
Ouch! And thanks. Well, it's obvious that we have a lot of improvements to do on our documentation! We'll take your experience to heart as we're now working on a major update of our API-docs. I'll get back to you once we've improved our docs and hopefully your next review will be a bit more positive.

As to your question on 27 I guess one of the mistakes we've made is that we wrongfully assumed that API-users would begin with a search, e.g. http://www.europeana.eu/portal/api/console.html?function=search&query=multatuli and then pick up the id and/or provided record call directly from the response (both are included) for the full record call, e.g. http://www.europeana.eu/portal/api/console.html?function=record&profile=full&recordId=%2F92062%2F8E88751AB5BC3D950E96A4C92505DB8600BB99C4

Bad assumption.

Cheers,
David

RubenVerborgh commented on 28 Nov 2013 Author Owner

Hi David,

Thanks for getting back on this, I appreciate it and would be glad to check out the improved version.

Documentation is indeed one part (and often neglected, but you obviously invested a lot in it). The assumption you mention is an important one. It indicates that people had an RPC-style scenario in mind: first call this, then call that.

For me, a huge collection is all about the resources and how they interlink, and not so much about a sequence of operations performed on ...nately, is about API design as well and I know that is much more difficult to change than documentation. I'm

Verbindung wird hergestellt...

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39:04 49:53

27% 39:04/49:53

Point in Case

https://ras.papercept.net/conferences/scripts/start.pl

41:20

41:20 49:53

27% 41:20/49:53

Simon Mayer

ras.papercept.net/conferences/scripts/start.pl

IEEE Robotics and Automation Society

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	Type of submission	Open	Deadline	
First submissions	Contributed paper	January 10, 2020	March 1, 2020	Closed
	Organized session proposal	January 10, 2020	February 1, 2020	Closed
	Organized session paper	January 10, 2020	March 1, 2020	Closed
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	Tutorial proposal	January 10, 2020	March 20, 2020	Closed
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	Keynote Talk	May 1, 2020	June 1, 2020	Closed
	Lifetime Talk	May 1, 2020	June 1, 2020	Closed
	Late Breaking Results Poster	June 21, 2020	July 21, 2020	Closed
	TRO submission	May 1, 2020	May 30, 2020	Closed
	RAM submission	May 1, 2020	May 24, 2020	Closed
Final submissions	Contributed paper	June 30, 2020	July 31, 2020	Log in
	Organized session paper	June 30, 2020	July 31, 2020	Log in
	Special Forum	June 30, 2020	September 2, 2020	Log in
	Cutting Edge Forum	June 30, 2020	September 2, 2020	Log in

41:46 49:53
27% 41:46/49:53

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Mayer, Simon

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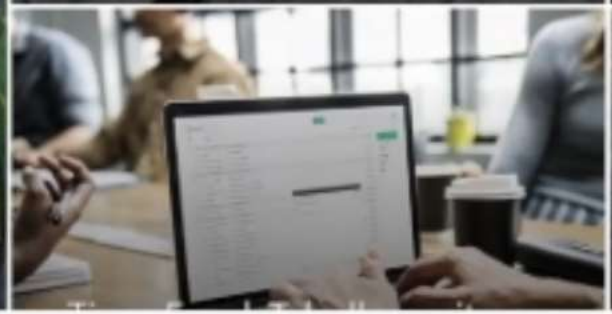

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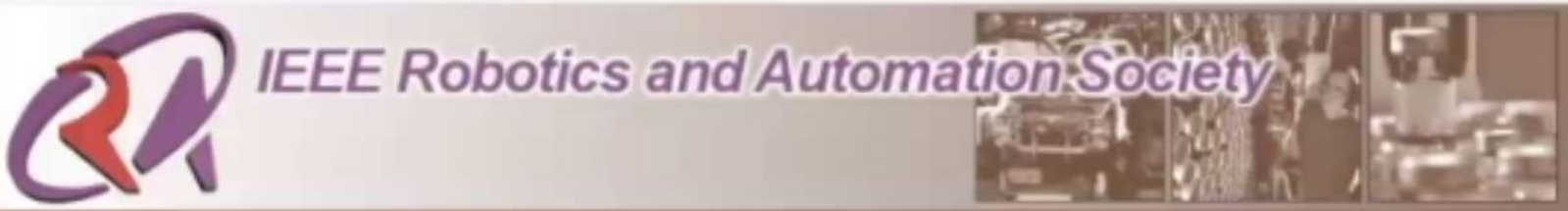

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42:26

42:26 49:53

27% 42:26/49:53

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42:34

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42:34 49:53

27% 42:34/49:53

Properly using URLs

Principle: A resource should relate a URL to a concept

http://example.org/songs/showDetails.php

vs.

http://example.org/songs/3563642

What does this URL represent?
Is it useful to **bookmark** this URL?
Is it useful to **share** this URL?

43:27 49:53
27% 43:27/49:53

Source: R. Verborgh, Web Fundamentals

Supporting Statelessness

Principle: Each message should be self-descriptive

/songs?artist=5521		*/songs?artist=5521*
/?page=2	*vs.*	*/songs?artist=5521&page=2*
/?page=3		*/songs?artist=5521&page=3*

What does this URL represent?
Is it useful to **bookmark** this URL?
Is it useful to **share** this URL?

44:02
44:02 49:53
27% 44:02/49:53

Making use of Hypermedia

Principle: The interaction should be driven by hypermedia

```
{ "title": "Baba O'Riley", "artist": { "id": 5521 } }
```

vs.

```
{ "title": "Baba O'Riley", "artist": { "id": "http://example.org/artists/5521" } }
```

Can I derive a **useful next interaction** from this?

44:54 49:53
27% 44:54/49:53

Source: R. Verborgh, Web Fundamentals

Controlling API Access

Pattern in many online services: **Websites are open,** but require **API keys** for machine access

- *"We need to rate-limit machine access"*
- *"We need to track automated access"*
- *"We need to protect our data"*

But they **break things** by personalizing URLs and thereby blocking the bookmarking, sharing and caching of resource representations

API keys don't help with this, since **the HTML website contains the exact same information without a key.** In other words: **one can extract all data from HTML, it's just more tedious!**

More complex/costly ways of "protecting" API access have similar problems…

Example: Twitter Search API (https://developer.twitter.com/en/docs/tweets/search/overview)

Take-home idea: protect your **resources**, not your **resource representations**!

46:48
46:48 49:53
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46:48/49:53

Better API Design for Machine Clients

Ideally, use the **same resources** that your human-centered website is based on and just **extend that site with machine-readable, linkable, representations.** Ideally, your machine API then **does not require documentation** (just like a human-centered website)

Take care though:

- Encouraging clients to have code **generated from an API description** is a can of worms, as clients are then tightly coupled with your API!
- This was (historically) on of the central problems of the WS-* specifications: clients were hard-compiled against API descriptions!

If your API gives access to a physical thing, consider these best practices:
http://w3c.github.io/wot/current-practices/wot-practices.html

Next, we put these best practices in context through a (brief) look at the **Web Architecture**

Our Menu

From the IoT to the WoT: Network-level and Application-level Interoperability

Discussion: Good Practices for Web APIs

Tidbits from the Web Architecture

Hypermedia APIs

49:39 49:53
27% 49:39/49:53

Let's take a break!

http://w3c.github.io/wot/current-practices/wot-practices.html